

# Venus Exploration to 2050

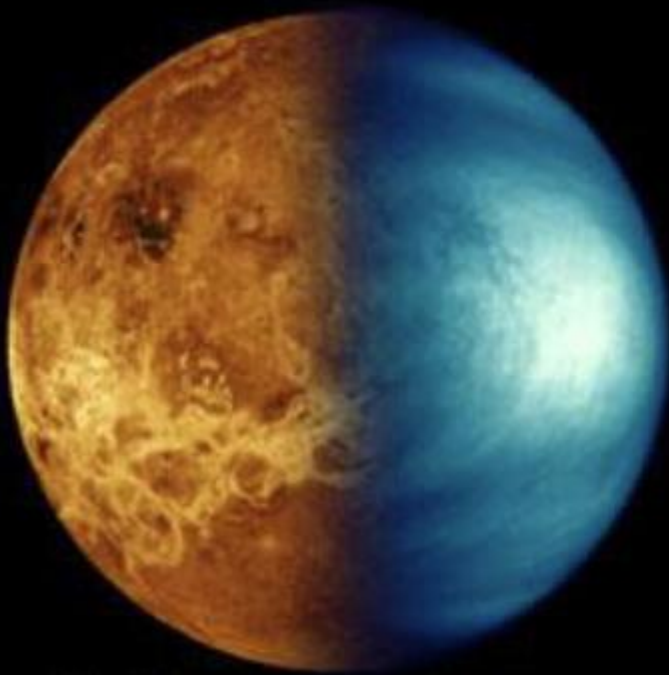
**James Cutts<sup>1</sup>, Robert Grimm<sup>2</sup>, Martha Gilmores  
and members of the VEXAG Steering Committee**

**Planetary Science Vision 2050 Workshop**

**Feb 27 to March 1, 2017**

1. Jet Propulsion Lab, California Institute of Technology, Pasadena, California
2. Southwest Research Institute, Boulder Colorado
3. Wesleyan University, Middletown, Connecticut

# Venus and Earth – Planetary Siblings



Magellan

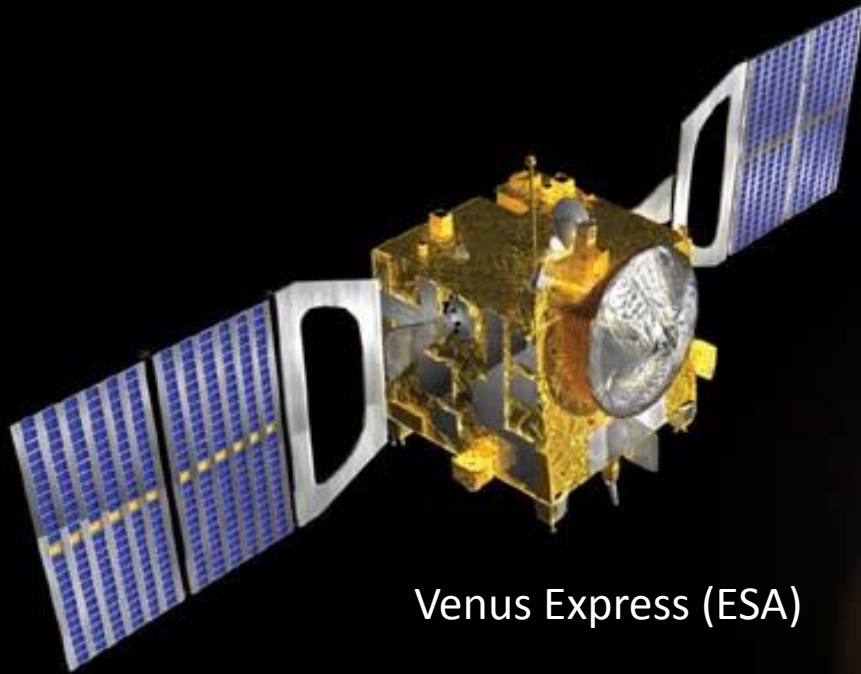
Galileo



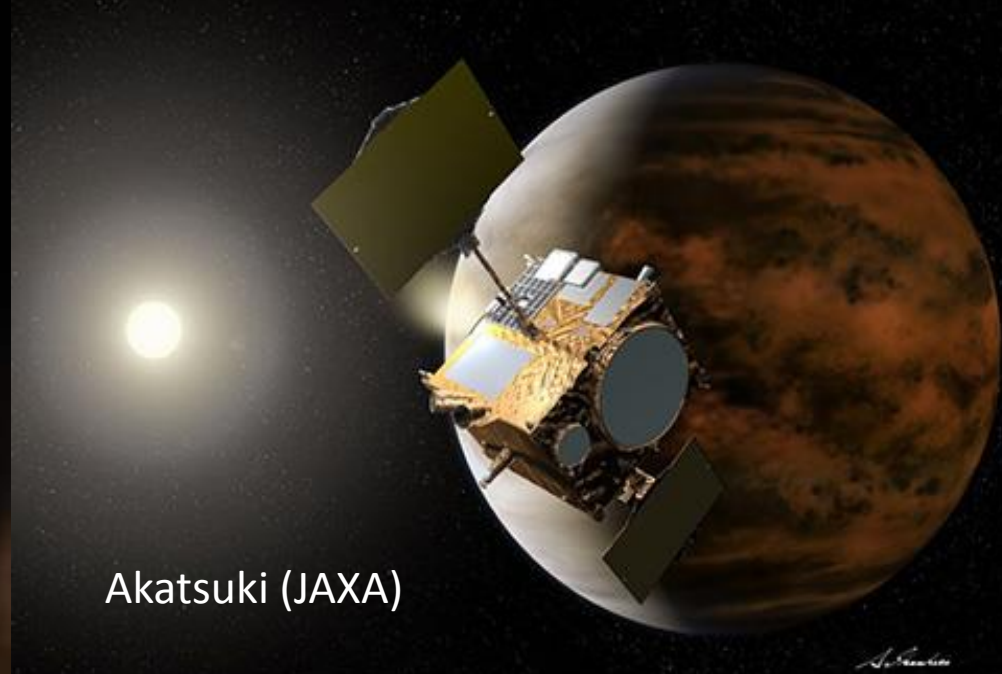
Apollo 17



# Venus – Recent and on going Missions



Venus Express (ESA)



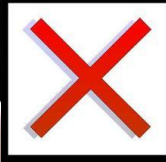
Akatsuki (JAXA)

- Orbit insertion April 2006.
- Mission ended December 2014
- Orbit insertion Dec 2015
- Five year mission is now planned

- Both missions primarily focus on investigations of the Venus atmosphere



# Proposed NASA and ESA Venus Missions



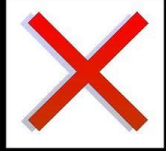
NASA Discovery  
Jan 2017  
Selection

**Veritas**

**EnVision**



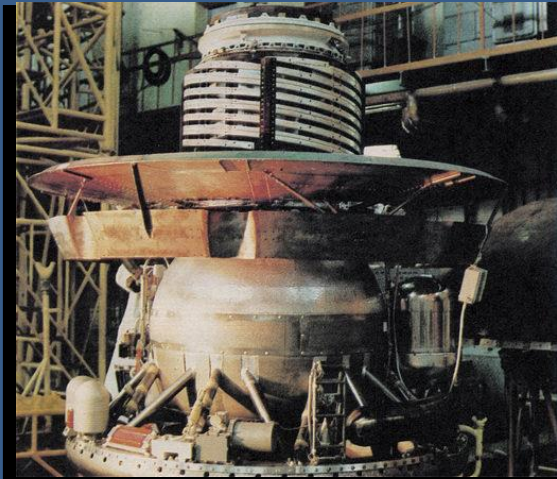
Cosmic  
Vision M5  
Opportunity  
2029 Launch



**DAVINCI**



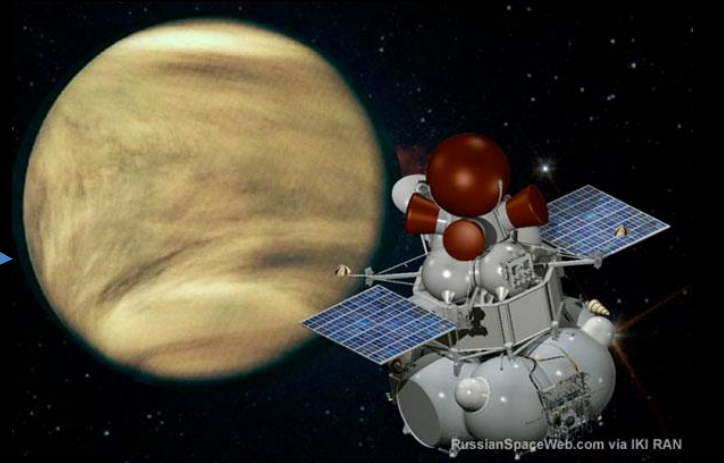
# Landed Missions – Past and Proposed



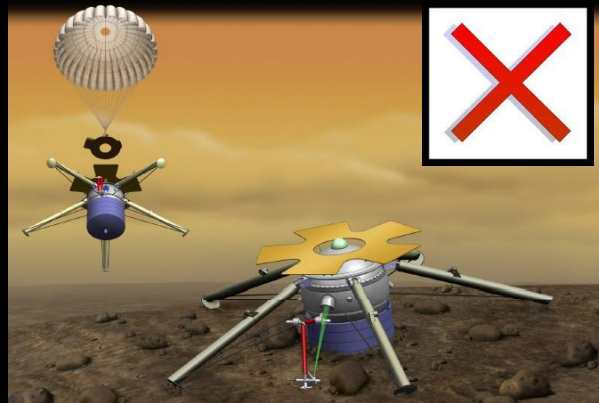
**VEGA (USSR, 1985)**



**~40 Years**



**Venera D (Russia, 2026 launch)**



**NASA New Frontiers 3 (2010)  
SAGE (JPL)**

*J. Cutts et. al.*



**NASA New Frontiers 4, 2017)**

Planetary Science Vision 2050

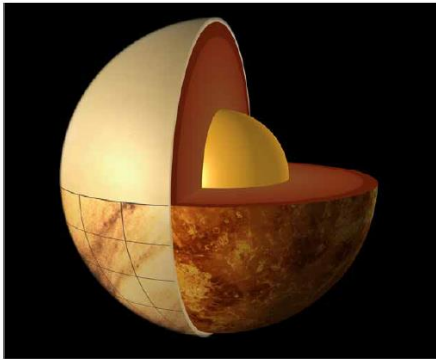


# VEXAG Venus Exploration Documents



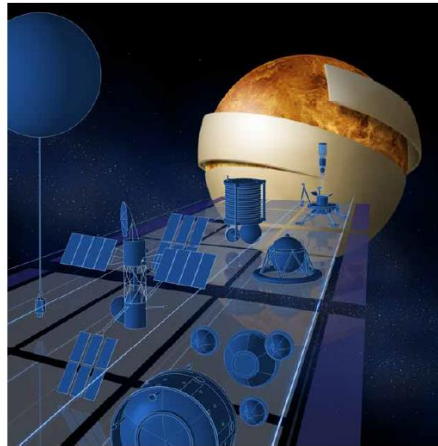
## *Goals, Objectives, and Investigations for Venus Exploration*

*May 2014*



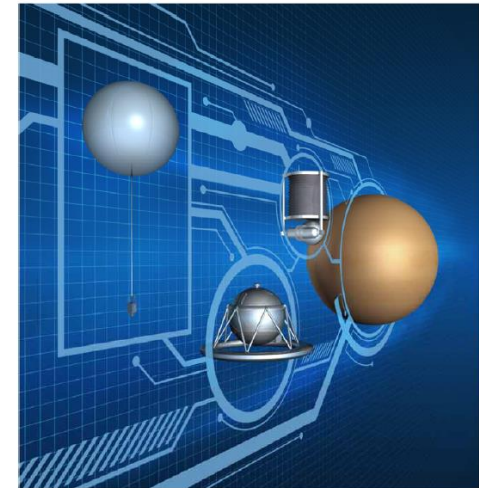
## *Roadmap for Venus Exploration*

*May 2014*



## *Venus Technology Plan*

*May 2014*



These documents, completed  
in May 2014, provide the  
essential framework for a  
program that can be executed  
by 2050

*J. Cutts et. al.*



All available on the VEXAG website;  
<http://www.lpi.usra.edu/vexag/>

Planetary Science Vision 2050 -5

## Atmosphere

- How did the atmosphere form and evolve?
- What controls the atmospheric super-rotation and greenhouse?
- What is the impact of clouds on climate and habitability?

## Surface & Interior

- How is heat released from the interior and has the global geodynamic style changed with time?
- What are the contemporary rates of volcanism and tectonism?
- How did Venus differentiate and evolve over time?

## System Interactions & Water

- Was surface water ever present?
- What role has the greenhouse had on climate history?
- How have the interior, surface, and atmosphere interacted as a coupled system over time?



# Strategies for Future Venus Exploration



- Apply instrument technologies developed for other planetary destinations on traditional Venus platforms (orbiters, probes, short duration landers)
- Exploit miniaturization of instrumentation and spacecraft such as cubesats including experiments requiring multiple spacecraft
- Deploy experiments on long lived aerial platforms (balloons or airplanes) operating in cooler parts of the atmosphere
- Develop Venus-specific techniques exploiting unique Venus characteristics such as dense atmosphere and near isothermal surface regions
- Develop high temperature technologies to enable long duration surface and near-surface exploration – NASA HotTech program initiated in FY16





- Near-Term, in priority order
  - New thermal protection systems (TPS).
  - High-temperature subsystems and components for long-duration (months) surface operations.
  - Aerial platforms for similar long-duration operations in the atmosphere
  - Deep-space optical communications
- Mid- and Far-Term, in priority order
  - Advanced power and cooling technology for long-duration surface operations.
  - Advanced descent and landing

Currently funded

No NASA PSD funding at this time

# Flyby and Orbital Missions Proposed Roadmap

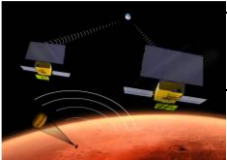


## Venus Gravity Assist Science Opportunities (VeGASO)

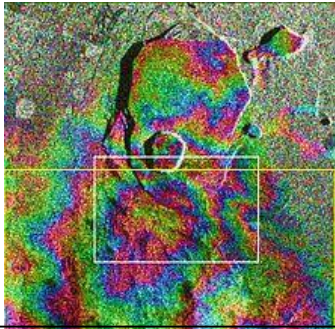
Bepi Columbo, Solar Orbiter, Solar Probe Plus

## Humans to Mars

EVME or EMVE trajectories



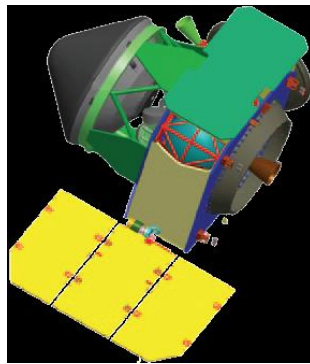
## Cubesat and SmallSat Opportunities



## Orbital Remote Sensing

- Radar
- IR imaging
- Gravity
- Topography

**Near Term**



## Venus Climate Mission



## Venus Aeronomy

**Mid Term**

**Far Term**

# Aerial Mobility Proposed Roadmap

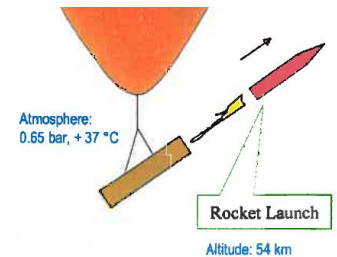


Lateral mobility



Hybrid Airship (VAMP)

Surface sample Return



Superpressure Balloon

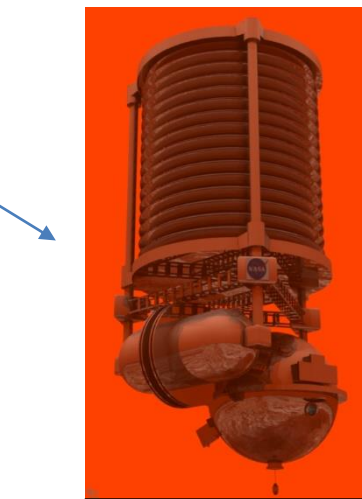
Altitude Control



AM-SAC Aerostat

In Situ Sample Analysis @ 54km)

Dual Balloon concept for raising Venus Surface Samples to 55 km altitude



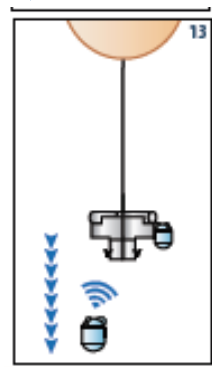
Venus Mobile Explorer

Far Term

Near Term

Mid Term

Deploy probes and sondes

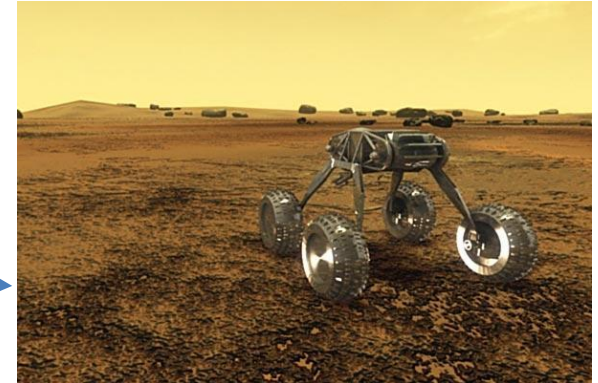


# Surface Exploration Proposed Roadmap



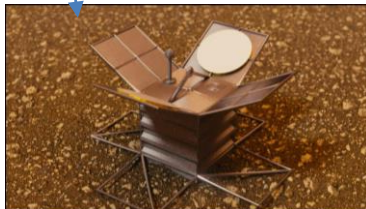
Passively cooled Venus  
Lander Lifetime 2-5  
hours

Radioisotope  
Power System  
Active cooling



Rover with hybrid approach to  
environmental survival

High temperature  
electronics



Long-lived In Situ  
Solar System  
Explorer (LISSE)

High temperature  
electronics



Surface Seismological  
stations

**Geophysical  
Network**

**Near Term**

**Mid Term**

**Far Term**





## POSTER TALKS (Title/Author/SESSION)

- Venus Sample Return by E Shibata (Purdue U)

## POLICY PATHWAYS AND TECHNIQUES SESSION

## PRINT ONLY (Title/Author/SESSION)

- Venera-D by David Senske

## WORKINGS

- Venus Aerial Platforms by James Cutts

## POLICY PATHWAYS AND TECHNIQUES SESSION

- Power Technology by S. Surampudi

## POLICY PATHWAYS AND TECHNIQUES SESSION

- Humans at Venus by Noam Izenberg

## POLICY PATHWAYS AND TECHNIQUES SESSION

- PS Vision 2015 Sanjay Limaye and Kandis Jessup

## WORKINGS



# Whither Venus?



- Community interest in Discovery missions still high; Both VERITAS and DAVINCI were “selectable.” Future proposals can be expected.
- New Frontiers Venus In Situ Explorer (VISE) is the next competitive opportunity for Venus
- Foreign missions with and without international collaborations (Akatsuki, Venera-D, EnVision), are an essential part of future planning
- Low cost, small satellite missions can take advantage of Venus’ proximity to Earth and produce important new science
- Venus flagship was endorsed in 2013 Decadal Survey. This will be updated for the 2022 Decadal with new capabilities.
- Investments in technology are vital to further progress leading to long duration surface and near surface missions and surface sample return
- A U.S. led mission is needed soon to engage the remaining pool of Magellan experience and invigorate the next generation of US Venus scientists.



**For more information visit**  
<http://www.lpi.usra.edu/vexag/>